3.1.2 Radiation Induced Electro-Motive Force (RIEMF) Effect in Irradiated Mineral Insulated Cable Coils

<u>EFDA Task:</u> TW3-TPDC-IRRCER-D7

<u>Field:</u> Physics Integration: Assessment of Diagnostic Sensors under Radiation

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OBJECTIVES

The study of the radiation-induced electromotive force (RIEMF) effect in cables is mainly motivated by its impact on the magnetic coil diagnostics to be used on ITER. The mineral-insulated (MI) cables used for these coils will receive a very high gamma and neutron flux and will therefore induce voltages and currents, which can spoil the measurements. A better understanding of these phenomena allows for a minimisation of these effects.

ACHIEVEMENTS

The results of the work performed in 2002 on RIEMF effects in cables showed very consistent results that were well understood via a comparison with a Monte Carlo modelling. However, one specific feature remained unexplained: the presence of a strong prompt current component, whose amplitude and even sign depended critically on the orientation of the rig in which the cables were mounted. Also the experiments were limited to cables with stainless steel, nickel and inconel core wires, while, for application in ITER, copper cores are envisaged.

To investigate both the orientation dependence of the prompt cable currents and the influence of copper as core wire material, a new rig was designed. It contained six identical cables (MgO insulated, AISI-304L-sheathed, outer diameter 1 mm) except that the cores were copper for three of them and AISI-304L for the other three. The cables were mounted parallel to each other on an aluminium tube with mutual angular separations of about 60° (Cu at 30°, 150° and 270°, AISI-304L at 90°, 210° and 330° relative to a predefined reference). As also other cables were assembled nearby (signal cables of self-powered neutron detectors, gamma thermometers and thermocouples to monitor the irradiation conditions), the influence of additional neighbouring metallic parts could also be studied.

The currents induced in the six mineral insulated cables were recorded continuously while changing the vertical position (i.e. varying the integrated neutron flux and gamma heating rate over the cables) and the orientation of the rig. Measurements were performed in two BR2 channels: one central channel with thermal fluxes up to 3 10^{14} n/cm²s and gamma heating rates up to 3.5 W/g, and one reflector channel with thermal neutron flux 1.4 10^{14} n/cm²s and gamma heating rate of 1.2 W/g. A typical example of such results is given in Figure 1. The preliminary analysis of the copious data shows two remarkable features: a dependence on the rig orientation and a specific parasitic effect when copper is used.

Dependence on rig orientation

Apart from the expected delayed current contributions - due to activation and subsequent beta decay of ^{27}Al (from the support tube), ^{55}Mn (from AISI-304L) and ^{65}Cu (from the copper core wire cables) - all cables show important prompt currents, depending strongly on the rig orientation. This effect had been observed before, but the actual data show a remarkable internal consistency with respect to orientation dependence (Figures 2a and 2b). For each cable a continuous trend can be seen with a maximum around 180° (a little higher in the central reactor channel) for the cables mounted without any neighbouring cable (cables 1, 3 and 6) and with shifted maxima for the other cables. This depends on the relative orientation of the neighbouring cables, in such a way that the highest signals are obtained for those positions where a maximal screening exists for the radiation flux coming predominantly from the 0° direction. Despite the internal consistency of the data, the origin of this prompt current could not be assessed so far. Previous assumptions pointed towards processes induced by a directional gamma field. However, in this case a behaviour opposite to the observed one would then actually be expected. The presence of metal in front of the cables would indeed cause more electrons to enter the cable from outside, leading to a more negative current. Moreover, just after reactor stop, when a significant gamma heating rate is still present, the signals show no orientation dependence anymore. Further investigations are going-on to clarify the origin of this phenomenon.

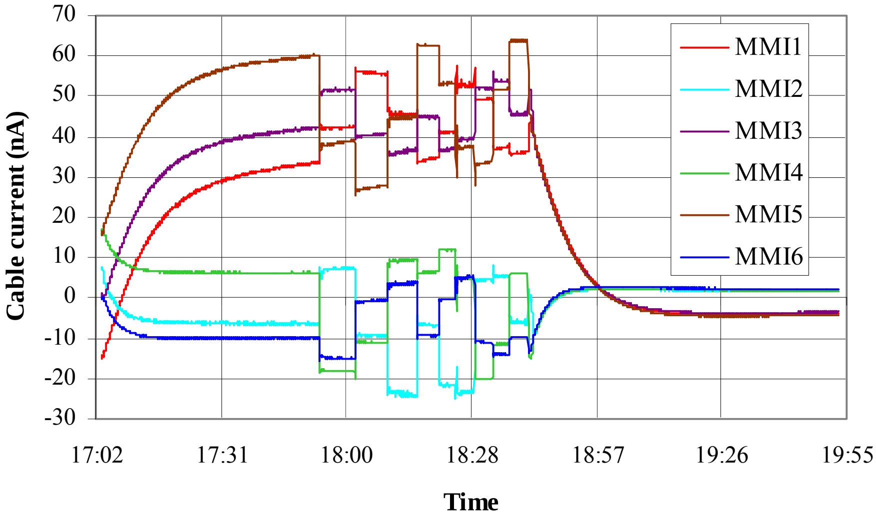

Fig. 1: Recorded cable currents while the cables are being inserted from the top until 10 cm below the reactor mid-plane. After a 50' stabilisation period, the rig orientation was changed discretely nine times before removing the rig from the flux. MMI1, 3 and 5 have a Cu core wire, MMI2, 4 and 6 an AISI304L core wire.

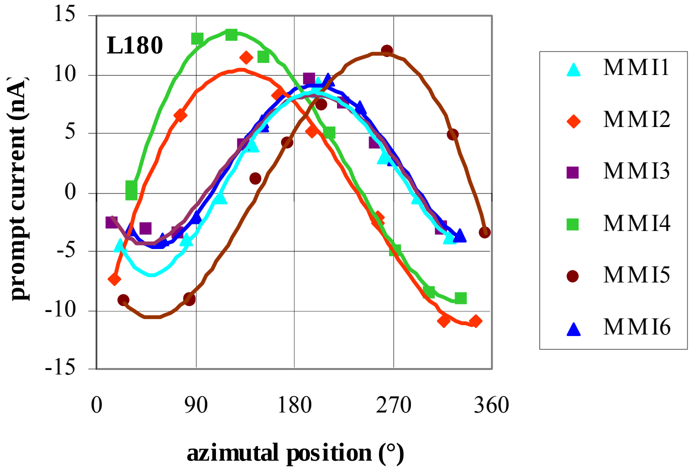

Fig. 2a: Prompt contributions of the cable currents as a function of their azimuthal position recorded during irradiation in the BR2 channels L180 (reflector).

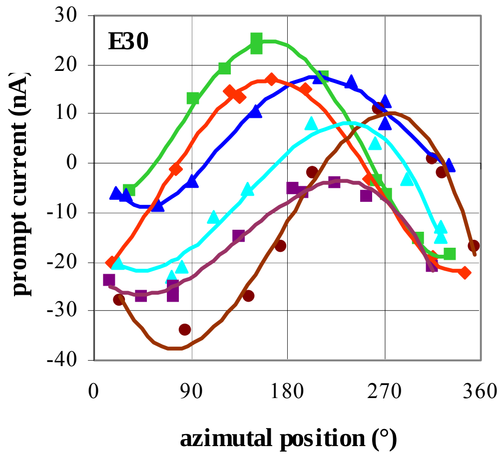

Fig. 2b: Prompt contributions of the cable currents as a function of their azimuthal position recorded during irradiation in the BR2 channels E30 (central).

Parasitic effects with copper cores

When inserted sufficiently deeply in the hottest channel (central channel) the copper cables exhibit a relatively strong signal component (of the order of 20 nA) that grows quasi-exponentially with a time constant of about 50 minutes, but then disappears quickly when the cables are pulled out of the flux. As the measurement of the current was performed by detecting the voltage over a fixed load resistance, it is not sure whether this signal stems from a real induced current or whether some parasitic voltage (possibly of thermoelectric origin) is developing between the core wire and the sheath. This will be investigated further during upcoming irradiations. Similar effects have been reported by the Japanese ITER Home Team. Our data suggest that such effects could be related to the choice of copper for the core wires and could be circumvented by another choice for the conductor material.

REFERENCES

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